501.43236X00

SUBSTITUTE SPECIFICATION

DISPLAY DEVICE

BACKGROUND OF THE INVENTION

The present invention relates to a display device, especially to a liquid crystal display device; and, more particularly, the invention relates to a liquid crystal display device which is incorporated into a projector, for example.

A liquid crystal display device is configured such that transparent substrates, which are arranged to face each other with liquid crystal material sandwiched therebetween, constitute an display panel, and a large number of pixels are provided in a matrix array for producing an image by controlling the liquid crystal material. For this purpose, each pixel includes a pair of electrodes, and the optical transmissivity of the liquid crystal material in each pixel is controlled by an electric field which is generated between these electrodes.

A liquid crystal display device which is incorporated into a projector is configured to transmit light received from a light source through the liquid crystal display device and to enable the display of images which are obtained from respective pixels of the liquid crystal display device on a screen.

There is currently a demand for further enhancement of the contrast of a display which has been produced by a liquid crystal display device for a projector. This is because the image displayed by the projector is displayed on a large screen, and, hence, a so-called presence is strongly demanded.

Here, as the liquid crystal display device, there is a so-called reflective-type liquid crystal display device, wherein light from a light source is reflected on reflectors, which also function as pixel electrodes of respective pixels, so as to project images on a screen. In this case, it has been confirmed

that the light from the liquid crystal display device contains light reflected from the vicinity of so-called spacers that are provided for ensuring a gap between a pair of transparent substrates, and so the contrast of the display is deteriorated due to this reflection of light. The uniformity of the orientation film is not sufficient in the vicinity of the spacers (referred to as domain regions), and these regions are recognized as the cause of leaking of light in a black display produced in a so-called normally white mode.

Here, this demand is not limited to a liquid crystal display device for a projecting portion, and a similar phenomenon occurs in the above-mentioned manner with respect to other liquid crystal display devices having a reflective type constitution.

The present invention has been made in view of such circumstances, and it is an object of the present invention to provide a liquid crystal display device in which the display contrast is enhanced.

SUMMARY OF THE INVENTION

A summary of typical aspects of the invention disclosed in this specification is as follows.

Example 1

In the liquid crystal display device according to the present invention, which includes, for example, respective substrates which are arranged to face each other in an opposed manner with liquid crystal material sandwiched therebetween, and reflection films which are formed on pixel regions on a liquid-crystal-side surface of one of the respective substrates so that light from the other substrate side is incident on the reflection films through the liquid crystal material and, thereafter, is reflected toward the other substrate side, the formation of the reflection films is not provided in the vicinity of projecting portions which are formed in the pixel regions.

Example 2

In the liquid crystal display device according to the present invention, which includes, for example, respective substrates which are arranged to face each other in an opposed manner with liquid crystal material sandwiched therebetween, and reflection films which are formed on pixel regions on a liquid-crystal-side surface of one of the respective substrates so that light from the other substrate side is incident on the reflection films through the liquid crystal material and, thereafter, is reflected toward the other substrate side, the formation of the reflection films is not provided in the periphery of spacers which are formed in the pixel regions.

Example 3

In the liquid crystal display device according to the present invention which includes, for example, respective substrates which are arranged to face each other in an opposed manner with liquid crystal material sandwiched therebetween, and reflection films which are formed on pixel regions on a liquid-crystal-side surface of one of the respective substrates so that light from the other substrate side is incident on the reflection films through the liquid crystal material and, thereafter, is reflected toward the other substrate side, the formation of the reflection films is not provided in the periphery of spacers formed in the pixel regions, and in portions of the pixel regions except for portions which face a direction of rubbing on an orientation film which is brought into contact with the liquid crystal.

Example 4

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of any one of means 1, 2 and 3, characterized in that the reflection films also function as one of the electrodes which controls the optical transmissivity of the liquid crystal material together

with the other electrode formed on a liquid-crystal-side surface of the other substrate.

Example 5

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of any one of Examples 2, 3 and 4, characterized in that the reflection films are formed over the whole areas of the pixel regions except for the vicinities of the spacers.

Example 6

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of any one of Examples 2, 3 and 4, characterized in that the reflection films are formed on one portion of the pixel regions, except for the vicinities of the spacers, and light transmitting electrodes which are electrically connected with the reflection films are formed in other portions of the pixel regions.

Example 7

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of Example 1, characterized in that switching elements, which are operated in response to scanning signals from gate signal lines and which supply video signals from drain signal lines to the reflection films, are formed on the liquid-crystal-side surface of one substrate, and the projecting portions are portions which are present on a surface which is brought into contact with the liquid crystal material due to the switching elements.

Example 8

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of any one of Examples 2, 3, 5 and 6, characterized in that the spacers are formed of columnar spacers which

are formed by selectively etching a material layer formed on a liquid-crystal-side surface of one substrate.

Example 9

The liquid crystal display device of the present invention includes, for example, columnar spacers which are formed by selectively etching a material layer and an orientation film which is formed after the formation of the spacers on a liquid-crystal-side surface of one of the respective substrates, which are arranged to face each other in an opposed manner with liquid crystal sandwiched material therebetween, wherein the diameter of the spacers is set to a value equal to or less than 1.55μm and the film thickness of the orientation film is set to a value equal to or less than 20nm.

The present invention is not limited to the above-mentioned Examples, and the constitutions of embodiments to be described later and various modifications thereof are conceivable without departing from the technical concept of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatic plan view showing one embodiment of an arrangement of pixels in a liquid crystal display device according to the present invention;

Fig. 2 is an equivalent circuit diagram showing one embodiment of a liquid crystal display part of the liquid crystal display device according to the present invention;

Fig. 3 is a diagrammatic cross-sectional view showing one embodiment of the pixel construction of the liquid crystal display device according to the present invention;

Fig. 4 is a diagrammatic plan view showing another embodiment of the pixel arrangement of the liquid crystal display device according to the present

invention;

Fig. 5 is a diagrammatic plan view showing another embodiment of the pixel arrangement of the liquid crystal display device according to the present invention; and

Fig. 6 is a diagrammatic cross-sectional view of another embodiment, showing the spacers and the vicinities thereof of the liquid crystal display device according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described in conjunction with the drawings, which show various embodiments of the present invention.

Embodiment 1.

<< Equivalent circuit >>

Fig. 2 is an equivalent circuit diagram of a liquid-crystal-side surface of one of the respective substrates which are arranged to face each other with liquid crystal material sandwiched therebetween. Although the drawing shows an equivalent circuit, the drawing depicts the construction corresponding to an actual geometric arrangement of the elements.

In the drawing, gate signal lines GL extend in the x direction and are arranged in parallel in the y direction in the display region. Further, drain signal lines DL extend in the y direction and are arranged in parallel in the x direction, and they are formed such that the drain signal lines DL are insulated from the respective gate signal lines GL. Respective rectangular regions, which are defined by adjacent gate signal lines GL and drain signal line DL, constitute pixel regions, and an array of these pixel regions constitutes a liquid crystal display part.

Further, each pixel region is provided with a thin film transistor TFT

having a MIS (metal Insulator Semiconductor) structure, and a gate electrode of the thin film transistor TFT is connected to the gate signal line GL which is arranged therebelow, as seen in the drawing, for example. Further, a drain electrode of the thin film transistor TFT is, for example, connected to the drain signal line DL located to the left thereof, as seen in the drawing, while a source electrode of the thin film transistor TFT is connected to a pixel electrode PX.

Thus, video signals from the drain signal line DL are supplied to the pixel electrode PX through the thin film transistor TFT, which is turned on when scanning signals are supplied thereto from the gate signal line GL. As a result, an electric field is generated between the pixel electrode PX and a counter electrode (not shown in the drawing) which is formed in common with the respective pixel regions on a liquid-crystal-side surface of the other substrate, and the optical transmissivity of the liquid crystal material disposed between the respective electrodes is controlled due to the electric field.

With respect to the pixel electrode PX, a capacitive element Cadd is connected between the pixel electrode PX and a capacitive signal line CL which runs inside the pixel regions substantially in parallel to the gate signal line GL. The video signals supplied to the pixel electrodes PX can be stored for a relatively long time due to the provision of this capacitive element Cadd.

<< Constitution of pixel >>

Fig. 3 is a cross-sectional view showing the constitution of a typical pixel in the above-mentioned pixel region. First of all, out of the respective substrates which are arranged to face each other with the liquid crystal material disposed therebetween, one substrate SUB1 is constituted as a silicon substrate. On the liquid-crystal-side surface of the substrate SUB1, by forming impurity diffusion layers, the source regions and the drain regions of the thin film transistors TFT and one electrode of the capacitive elements Cadd are formed.

Further, on a surface of the substrate SUB1 formed in this manner, a first insulation film is formed, and the gate signal lines GL are formed on an upper surface of the first insulation film. In forming the gate signal lines GL, the gate electrodes GT of the thin film transistors TFT and the other electrode of the capacitive elements Cadd are formed. In this case, the first insulation film functions as a gate insulation film in regions where the thin film transistors TFT are formed, and it functions as a dielectric film in regions where the capacitive elements Cadd are formed.

On the surface of the substrate SUB1 having such a constitution, a second insulation film is formed such that the second insulation film also covers the gate signal lines GL and the like, and the drain signal lines DL are formed on an upper surface of the second insulation film. In forming the drain signal lines DL, the drain electrodes of the thin film transistors TFT, which are electrically connected with the drain signal lines DL, are formed. Further, the source electrodes, the wiring layers which are connected with the source electrodes and the other electrode of the capacitive elements Cadd and the like are also formed.

On the surface of the substrate SUB1 having such a constitution, a third insulation film is formed, such that the third insulation film also covers the drains signal lines DL. On an upper surface of the third insulation film, a first light shielding film IL1, which also functions as a wiring layer, is formed. The function of the first light shielding film IL1 as a wiring layer is to pull out the source electrodes of the thin film transistors TFT to this layer and to form one electrode of another capacitive element which is formed in parallel to the above-mentioned capacitive element Cadd.

On the surface of the substrate SUB1 having such a constitution, a fourth insulation film is formed, such that the fourth insulation film also covers

the first light shielding film IL1 and the like. On an upper surface of the fourth insulation film, a second light shielding film IL2, which also functions as a wiring layer, is formed.

The second light shielding film IL2 is provided for ensuring reliable light shielding in the pixel region together with the first light shielding film IL1. Particularly, the second light shielding film IL2 is formed in such a way that the second light shielding film IL2 covers the region where the first light shielding film IL1 is not formed. Here, the second light shielding film IL2 and the first light shielding film IL1 are electrically connected to each other, and the source electrodes of the thin film transistors TFT are pulled out to this layer.

On the surface of the substrate SUB1 having such a constitution, a fifth insulation film is formed, such that the fifth insulation film also covers the second light shielding film IL2 and the like. On an upper surface of the fifth insulation film, the pixel electrodes PX are formed.

Then, on upper surfaces of the pixel electrodes PX, spacers SP are formed so as to ensure a gap between the transparent substrate SUB1 and the transparent substrate SUB2, which are arranged to face each other with the liquid crystal material LC disposed therebetween. The spacers SP are formed on the liquid-crystal-side surface of the substrate SUB1, and they are formed by selectively etching a material layer made of resin, for example, using a photolithography technique.

Here, although not shown in the drawing, after forming the spacers SP in this manner, an orientation film, to which rubbing treatment is applied, is formed on the whole area of the upper surfaces of the pixel electrodes PX. The orientation film determines the initial orientation direction of molecules of the liquid crystal material, which is brought into direct contact with the orientation film.

The transparent substrate SUB2 is arranged to face the substrate SUB1 having such a constitution in an opposed manner with the liquid crystal material sandwiched therebetween. On a liquid-crystal-side surface of the transparent substrate SUB2, a counter electrode CT is formed in common with respective pixel regions, wherein the counter electrode CT is formed of a light transmitting conductive film that is made of, for example, ITO (Indium Tin Oxide), ITZO (Indium Tin Zinc Oxide), IZO (Indium Zinc Oxide), SnO_2 (Tin Oxide), In_2O_3 (Yttrium Oxide) or the like. In this embodiment, the liquid crystal display device for projector is used as an example, and, hence, for example, black matrixes, color filters and the like are not formed on the liquid-crystal-side surface of the substrate SUB2.

In the liquid crystal display device having such a constitution, light LT is incident from the transparent substrate SUB2 side, and this light passes through the liquid crystal material, whose optical transmissivity is controlled by the electric fields generated between the pixel electrodes PX and the counter electrodes CT. The light is reflected on the pixel electrodes PX which form a reflection film, and, then, it is irradiated after again passing through the transparent substrate SUB2.

<< Constitution of pixel electrode in the vicinity of spacer >>

Fig. 1 shows a plan view of the pixel electrodes PX in respective pixel regions as viewed from the transparent substrate SUB2 side. The pixel electrode PX in each pixel region is formed over the whole area of the pixel region. This pixel electrode PX and the pixel electrode PX in another neighboring pixel region are electrically separated from each other with a slight gap therebetween, which is located over the drain signal line DL and the gate signal line GL.

On the respective four corners of each pixel region having a rectangular

shape, spacers SP are formed using the corners of another neighboring pixel region as a support base. Thus, the pixel electrodes PX have regions where the pixel electrodes PX are not formed in the vicinities of the spacers SP. In these regions, the layer (fifth insulation film) which is positioned as a layer below the pixel electrodes PX is exposed.

In other words, in the periphery around each spacer SP, there is a region in which the pixel electrode PX of each pixel region is not formed.

In this case, the pixel electrode PX is not formed, as shown in Fig. 1, at the regions where the spacers SP are formed and in the peripheries around the spacers SP. It is needless to say, however, as shown in Fig. 4, that the formation of the pixel electrode PX can be such that the spacers SP are formed on conductive layers CD (PX) made of the same material as the pixel electrodes PX, and the peripheries of the conductive layers CD(PX) are removed. By adopting the constitution shown in Fig. 4, the conductive layers CD(PX) function as support bases for the spacers SP, and, hence, the of the spacer SP can be reliably set to be equal to the height of the other spacers SP.

<< Advantageous effect >>

The liquid crystal display device having such a constitution is configured such that the portions of the reflection films (pixel electrodes PX) present around the peripheries of the spacers SP are removed, and, hence, ambient light which is incident on these portions is not reflected. The peripheries of the spacers SP have no regularity with respect to the rubbing direction of the orientation film and constitute domain regions, and, hence, these portions are substantially prevented from constituting the pixel regions. Accordingly, when the liquid crystal display device is used in the normally white mode, it is possible to obviate the leaking of light at these portions in the black display.

Here, by forming masks on these portions, it may be possible to provide

a constitution which prevents the reflection of the incident ambient light in the same manner as this embodiment. In this case, however, it is impossible to obviate an increase in the number of manufacturing steps in the formation of the masks and an increase in the areas of the masks to consider the tolerance and the like due to misalignment of respective transparent substrates when the masks are formed on the other transparent substrate side, which faces the one transparent substrate side.

By adopting the constitution of the above-mentioned embodiment, an increase in the number of manufacturing steps can be obviated, and, at the same time, the removal of the reflection films around the spacers can be minimized; and, hence, the reduction of the numerical aperture can be suppressed to a minimum.

Embodiment 2.

Fig. 5 is a plan view showing another embodiment of the liquid crystal display device according to the present invention, and it corresponds in general to the structure shown in Fig. 4.

The constitution which makes this embodiment different from the embodiment shown in Fig. 4 lies in the fact that, with respect to the periphery around each spacer SP, the reflection films (pixel electrodes PX) are not removed at portions which face the rubbing direction D of the orientation film at the substrate side on which the spacers SP are formed, while the reflection films on other portions are removed.

Out of the periphery of each spacer SP, the portions which face the rubbing direction of the orientation film are portions which do not constitute shades of the spacer at the time of performing the rubbing treatment; and, hence, the rubbing can be normally performed, whereby the portions do not constitute domain regions. Accordingly, the reflection films on these portions

are left. That is, the portions are left as substantial portions of the pixel regions.

The liquid crystal display device having such a constitution can suppress the removal of the reflection films in the peripheries around the spacers SP to a minimum, and, hence, the numerical aperture of the pixels can be enhanced.

Embodiment 3.

Fig. 6 is a diagram showing another embodiment of the liquid crystal display device according to the present invention, and it is a cross-sectional view showing the above-mentioned spacer SP and the vicinity thereof.

In this embodiment, first of all, the structure is such that the spacer SP has a diameter W of 1.55μm, and preferably less than this value.

Further, the film thickness t of the orientation film ORI, which is formed after formation of the spacer SP, is set to 20nm, and, more preferably, to less than this value.

The liquid crystal display device having such a constitution provides the advantage that the so-called wetting finish with respect to the spacer SP on the orientation film ORI is reduced by setting the film thickness of the orientation film ORI to a small value. That is, it is possible to decrease the gradient of the wetting finish with respect to the spacers on the orientation film ORI.

Accordingly, in rubbing the orientation film ORI, it is possible to form the regions of the orientation film ORI so as to have a reliable rubbing at positions extremely close to the spacer SP. In this case, by setting the film thickness of the orientation film ORI to a small value, the voltage applied to the liquid crystal can be increased, and, hence, it is also possible to obtain an advantageous effect in that the black luminance can be lowered, for example. This implies that the display contrast can be enhanced.

Further, by setting the diameter of the spacer SP to a small value, the diameter of the domain region about the spacer SP can be eventually made small, and, hence, the numerical aperture of the pixel can be enhanced.

The above-mentioned embodiments can be used individually or in combination. This is because the advantageous effects of the respective embodiments can be obtained in a single form or synergistically.

Further, it is needless to say that the present invention is not limited to a liquid crystal display device for use in a projector, and it is applicable to other types of liquid crystal display device. This is because the further enhancement of the contrast can be obtained also with respect to the conventional liquid crystal display device.

In this case, with respect to the conventional liquid crystal display device, black matrixes are formed on the liquid-crystal-side surface of one substrate. However, it is needless to say that the present invention is applicable to this case. This is because it is no longer necessary to cover the peripheries of the spacers with a black matrix, and. hence, the object of the present invention can be obtained without reducing the numerical aperture.

Further, with respect to the conventional liquid crystal display device, it is needless to say that the present invention is also applicable to a reflective-type liquid crystal display device, which is referred to as a partial transmissive liquid crystal display device. That is, this type of liquid crystal display device is configured such that, for example, the reflection films are formed on areas of the pixel regions, except for the center portions, and, at the same time, the light transmitting conductive films which are electrically connected with the reflection films are formed on the center portions, and the reflection films and the light transmitting conductive films constitute the pixel electrodes. The liquid crystal display device can be used in a divided form as a

reflective type liquid crystal display device, as well as a light transmissive type liquid crystal display device.

In this case, portions which differ from this embodiment lie in the presence of the light transmitting part in the pixel region and other portions have substantially the same constitution as this embodiment. Accordingly, the present invention is directly applicable to the regions where the reflective films are formed.

As can be clearly understood from the above-mentioned explanation, according to the liquid crystal display device of the present invention, a further enhancement of the display contrast can be obtained.